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# Multi-local evaluation of the agronomic performances of new sorghum lines in the villages of Riadi, Garin Maigari and on station at CERRA-Maradi

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**ABSTRACT**
The field trial was conducted in 2021 rainy season at RIADI (13°25'47" north latitude and 7°7'33" east longitude, GARIN MAIGARI (13°36'88" latitude North and 7°08'86" East longitude) and the CERRA-Maradi STATION (13°27'72" North latitude and 7°06'54" East longitude) in order to evaluate the agronomic performance of new sorghum genotypes and to identify among them the best adapted genotypes in term of grain yields. The experiment contains thirty (30) different varieties including 24 varieties resulting from the cross between MDK and L153-5 genotypes, two parents (MDK and L-153-5), two station checks (L28 and SSD 35) and two local checks in each location. The treatments were laid out in an incomplete randomized block design with three replicates in each location. The results revealed positive and negative correlations between some variables such as RDT G and RDT T, RDT G and PP, RDT G and NPR, RDT G and HTR. The combined ANOVA revealed significant effects of genotype (G), environment (E) and genotype x environment interactions (GxE). In addition, GGE Biplot analysis, highly performed genotypes in grain yield such as V68, V3 and V58 were identified among the genotypes. Some genotypes have a specific adaptation, these are the MDK, TL2G, L28 and V5 genotypes which are the best genotypes in the mega environment formed by GARIN MAIGARI and RIADI and V27 and V73 which are the best genotypes in RIADI. This analysis allowed also to identify genotypes such as SSD 35, V61, L28, V27, MDK which have medium unstable yield means and V13, V 47, V 43, V19, V29, V8 which are stable but produced lower yields (below average). It also showed a correlation between the STATION and GARIN MAIGARI which constitute a mega environment and showed that GARIN MAIGARI is the ideal environment (reference). So, it can be used for genotypes with wide adaptation while non-representative environments such as RIADI and STATION are suitable for selecting specifically adapted genotypes.

**Keywords**: sorghum, multi-local evaluation, new genotypes, agronomic performances.

# I. INTRODUCTION

A landlocked Sahelian country with a growing population, Niger is one of the driest countries in the world where it rains around three to four months a year. This country is experiencing difficulties in ensuring its food self-sufficiency.

Agriculture and livestock farming alone employ 85% of the active population and contribute to the national economy with a GDP of 43% (INS, 2014a). With an area of 1,267,000 km², Niger where agriculture occupies an important place in the socio-economic life of the populations, Niger has a large area of land of which only the southern strip (12%) constitutes a fertile and benefits from sufficient annual rainfall for the various crops without irrigation. Millet and sorghum are the main cereals cultivated both in terms of area sown, production and their contribution to food. These two cereals are cultivated in all regions of the country and occupy a privileged place except in Aïr (Idrissa, 2001, cited by Sadi, 2011). The place of sorghum is reflected above all by a considerable increase in sown areas which went from 2,544,700 ha in 2009 to more than 3,565,900 ha in 2013 (INS, 2014b). National production for the same period increased from 738,500 tons to 1,320,000 tons. Unfortunately, sorghum productivity remains very low, the national yield is equivalent to 343 kg/ha (INS, 2014b).

Agricultural production in Niger, as in the Sahel countries in general, is dependent on several factors, including the low fertility of cultivated land and the often deficit and irregular rainfall. In addition to these factors, sorghum production is limited by seed quality. The latter are obtained from traditional varieties generally with a long cycle. The grains matured during a period of high humidity. This hygrometry favors the establishment of pathogens (mold) altering the quality of sorghum seeds (Louvel, 1982 and 1983, cited by Louis, 1995).

In order to remedy this situation, several studies have been carried out, particularly in the context of the fight against drought which frequently occurs towards the end of crop cycles. Sorghum varieties better adapted to drought conditions have also been developed and popularized by research institutions such as INRAN and ICRISAT.

Despite these efforts, the main aim of which is to complement local varieties sensitive to the climatic conditions of the Sahel and to crop enemies with improved varieties adapted to these conditions, the use of local varieties remains the most dominant. This is explained by the unavailability of improved seeds among producers and the problem of choice of variety (Bassirou, 2014).

As a result, there is a growing need to increase sorghum productivity in Niger in response to these challenges and yield declines. To overcome this problem, a population resulting from the cross between MDK and L153-5 was developed in order to provide farmers with productive varieties adapted to the drastic conditions of Niger where among actions in favor of food security include the creation and/or introduction of new sorghum genotypes adapted to various environments in terms of soil and climate. It is in this same vein that this present work is carried out. The main objective of this work is a multi-local evaluation of the agronomic performances of new sorghum lines resulting from the crossing between MDK and L153-5 with the aim of identifying the best adapted lines with good productivity.

## II. MATERIALS AND METHODS

### 1. Plant material

This study includes thirty (30) lines of sorghum including 24 lines resulting from the cross between Matché Da Koumgna (MDK) a very productive late variety (3 t/ha) and L 153-5 a very early variety with low yield, two (2) lines from the INRAN sorghum program (L 28 and SSD 35) and two control varieties widely used locally at each of the three evaluation sites. Mota Maradi (MM) and El Rourouka for the INRAN Maradi research station site, Makaho da Wayo (MDW) and the Hakorin Karouwa (HK) variety for the Riadi site and finally the El Bazanga and MDW for the Garin Maigari site were used in this experiment.

### 2. Experimental site

The various experiments were carried out at three (3) different sites, namely the villages of Garin Maigari and Riadi and in the CERRA Maradi research station.

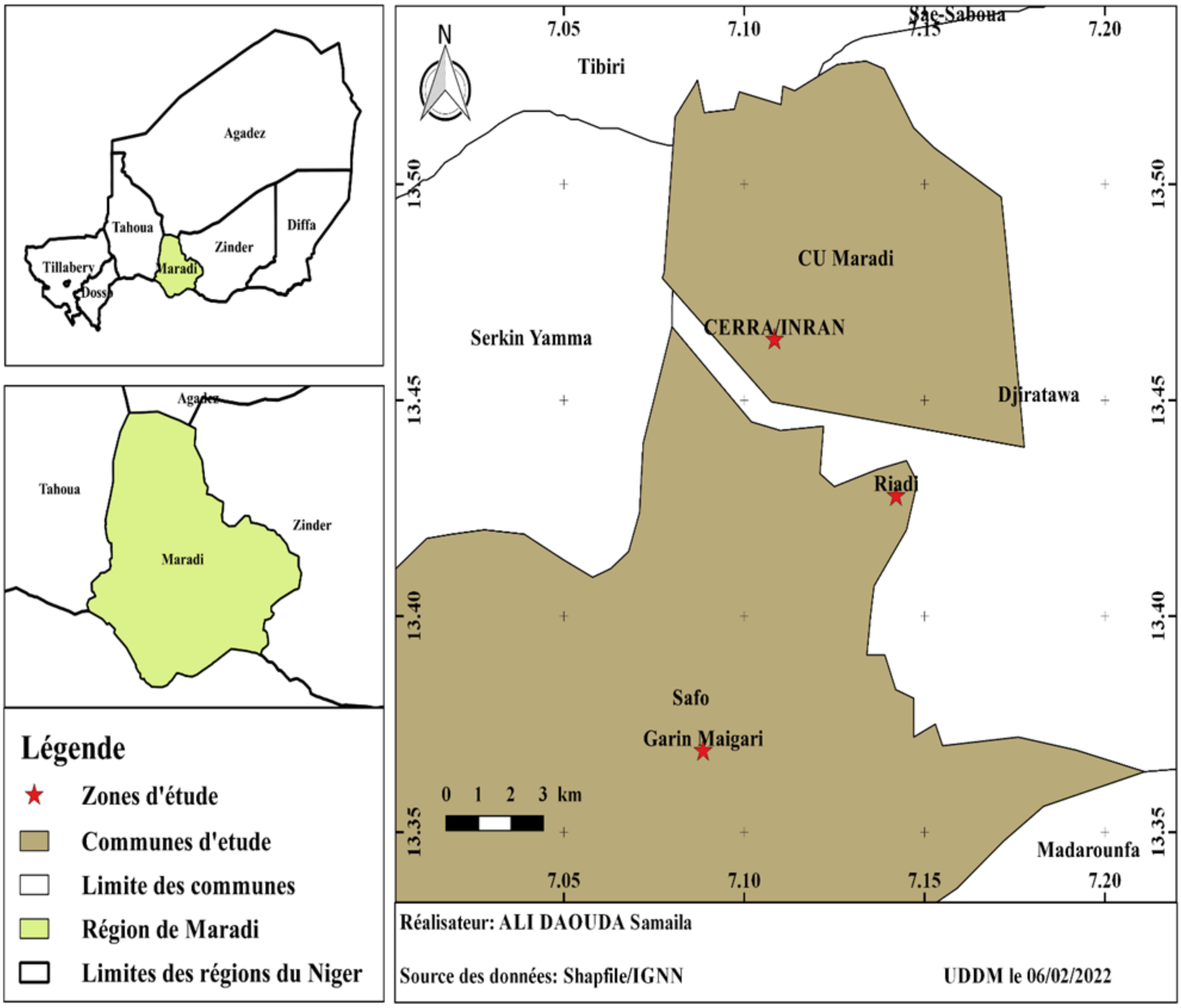


Figure 1: Representative map of the different experimental sites

### 3. Experimental design

The same experimental design was used on all sites. It is a randomized incomplete block design with three repetitions. Each repetition consists of 6 blocks of 15 $m^2$ which is made up of 5 varieties. The spacings between the lines are 0.80 m and 0.30 m between hills.

### 4. Data analysis

The data obtained were analyzed by the GENSTAT (software version 15). This software allowed to carry out the analysis of variance with the student test for the comparison of the means of the different varieties. A correlation matrix using the same software for all of the measured parameters was produced. It also allowed through GGE Biplot analysis methods, to evaluate the genotype x environment (GxE) interaction and identify the most efficient genotypes on the one hand and the most stable on the other.

**Data collected were:** VAR: Varieties; NPL: Number of hills Raised; 50% flo: 50% Flowering; HTR: Plant Height; MAT: Maturity physiology; NPR: Number of Panicles Harvested; PP: Panicle weight; RDT G: Seed yield; RTD T: Stem Yield; IR: Harvest Index; IB: Threshing Index, Tl1S: Local Witness 1 Station; Tl2S: Local indicator 2 Station; JAS = Days After Semi

## III. RESULTS

### 1. CERRA Maradi Station

At this site, for the 50% Flo variable, the TLS1 (MM) variety flowered very early with an average of 64.33 DAS and the V49 variety the latest with an average of 103.6 DAS. For the maturity variable (MAT), variety V49 recorded the highest average (118.7 DAS) and variety TLS1 recorded the lowest average (79.3 DAS).

In other words, at this site, the TLS1 variety (MM) was found to be the earliest with (79.3 DAS) while V49 was the latest with (118.7 DAS) (table 1). On the other hand, the averages of the other varieties are comparable. For this site no significant difference was observed for plant height (HTR). Regarding grain yields, the MDK variety is the most efficient with a yield of 1333.3 kg/ha while the V49 has the lowest yield (111.1 kg/ha). Indeed, for the average stem yield (RDT T) the MDK variety has the highest average with 5444 kg/ha and that of the V29 varieties the lowest (2831 kg/ha). For the variable number of panicles harvested (NPR), variety SSD 35 recorded the highest average (21 panicles) and V49 the lowest (2.67 panicles). Regarding the panicle weight (PP) variable, the MDK variety recorded the highest average (1.05 kg) and V49 the lowest (0.08 kg).

**Table 1: Performance of Sorghum varieties at CERRA Maradi**

| VAR | 50% flo | HTR | MAT | NPR | PP | RDT G | POI100 GR | RDT T | IR | IB |
|---|---|---|---|---|---|---|---|---|---|---|
| V49 | 103,6a | 130a | 118,7a | 2,67c | 0,08b | 111,1a | 4b | 5667ab | 2,70bc | 0,44ab |
| L 28 | 102,67a | 133,3a | 117,7a | 11,33abc | 0,20b | 777,8a | 4ab | 6256ab | 2,87bc | 1,91ab |
| V73 | 102,00a | 123,3a | 117a | 6abc | 0,10b | 166,7a | 4b | 5067ab | 2,52bc | 0,50ab |
| V39 | 101,33a | 101,7a | 116,3a | 16,67abc | 0,21b | 388,8a | 4b | 6917ab | 3,07bc | 0,55ab |
| V68 | 101,00a | 111,7a | 116a | 4,33bc | 0,16b | 333,3a | 4,33ab | 6572ab | 2,97bc | 0,61ab |
| V33 | 99,67a | 156,7a | 114,7a | 10,67abc | 0,15b | 250a | 3,33b | 12217bc | 4,66ab | 0,50ab |
| MDK | 98,67a | 116,7a | 113,7a | 20a | 1,05a | 1333,3b | 6a | 15444c | 5,63a | 0,39ab |
| V17 | 98,33a | 93,3a | 113,3a | 15,67abc | 0,26b | 444,4a | 4b | 6556ab | 2,96bc | 0,50ab |
| V61 | 97,33a | 146,7a | 112,3a | 7abc | 0,10b | 194,4a | 2,66b | 5222ab | 2,56bc | 0,55ab |
| V8 | 97,00a | 128,3a | 112a | 8,33abc | 0,15b | 227,8a | 4,66ab | 8972ab | 3,69bc | 0,55ab |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| V45 | 96,67a | 130a | 111,7a | 12,67abc | 0,33b | 388,9a | 4,66ab | 7989ab | 3,39bc | 0,36ab |
| V19 | 96,33a | 143,5a | 111,3a | 10abc | 0,13b | 250a | 4b | 8683ab | 3,60bc | 0,55ab |
| V40 | 96,33a | 91,7a | 111,3a | 6,67abc | 0,10b | 166,7a | 3,66b | 5111ab | 2,53bc | 0,50ab |
| V47 | 95,67a | 120a | 110,7a | 11abc | 0,16b | 227,8a | 4,33ab | 2556abc | 4,16abc | 0,50ab |
| V1 | 95,33a | 110a | 110,3a | 10,33abc | 0,25b | 361,1a | 4,66b | 6017ab | 2,80bc | 0,46ab |
| V27 | 94,67a | 100a | 109,7a | 10abc | 0,16b | 333,3a | 4,66b | 7861ab | 3,36bc | 0,61ab |
| V13 | 94,00a | 130a | 109a | 10abc | 0,15b | 227,8a | 3,66b | 4000a | 2,20c | 0,55ab |
| V3 | 93,67a | 110a | 108,7a | 14,33abc | 0,18b | 333,3a | 4,66ab | 8967ab | 3,69bc | 0,55ab |
| V48 | 93,67a | 158,3a | 108,7a | 7abc | 0,11b | 222,2a | 4b | 6111ab | 2,83bc | 0,66a |
| V29 | 93,33a | 86,7a | 108,3a | 7,33abc | 0,10b | 166,7a | 4,33ab | 2831a | 1,85c | 0,50ab |
| V70 | 91,00ab | 106,7a | 106ab | 8,67abc | 0,18b | 227,8a | 4,33ab | 5333ab | 2,60bc | 0,46ab |
| V37 | 87,00ab | 100a | 102ab | 18,67ab | 0,26b | 388,9a | 3,66b | 7556ab | 3,26bc | 0,48ab |
| V16 | 85,67ab | 126,7a | 100,7ab | 9abc | 0,16b | 333,3a | 4b | 4494ab | 2,35bc | 0,61ab |
| V5 | 85,67ab | 115a | 100,7ab | 7,67abc | 0,11b | 694,4a | 2,66b | 4344ab | 2,30bc | 2a |
| V50 | 84,33ab | 141,7a | 99,3ab | 12abc | 0,15b | 227,8a | 3,66b | 5000ab | 2,50bc | 0,55ab |
| L153-5 | 83,33ab | 115a | 98,3ab | 8,67abc | 0,10b | 166,7a | 3,33b | 2972a | 1,89c | 0,50ab |
| V58 | 83,00ab | 145a | 98ab | 17,67abc | 0,26b | 444,4a | 3,66b | 9222ab | 3,76bc | 0,50ab |
| TL2S | 74,67bc | 135a | 89,7bc | 16abc | 0,21b | 333,3a | 3,66b | 4778ab | 2,43bc | 0,51ab |
| SSD35 | 65,00c | 136,7a | 80c | 21a | 0,25b | 388,9a | 3b | 6350ab | 2,90bc | 0,51ab |
| TL1S | 64,33c | 135a | 79,3c | 12abc | 0,15b | 227,8a | 3,66b | 3111a | 1,93c | 0,55ab |

**Means followed by the same letter in the columns are not significantly different according to the LSD test at 5% probability**

## 2. RIADI

At the village of Riadi, dates of 50% flowering (50% FLO) of varieties are between 62.67 DAS and 98.33 DAS (table 2). The variety SSD 35 with 62 DAS is the first variety to reach this stage while the MDK and TL1R (MDW) varieties with 98.33 DAS represent the last. Physiological maturity (MAT) of varieties is reached between 77.67 and 133.33 DAS (table 2). This physiological maturity differs significantly depending on the variety. Indeed, SSD 35 with 77.67 DAS is the earliest variety while MDK with 133.33 DAS is the latest.

For the height parameter (HTR), the TL1R (MDW) variety recorded the highest average (265 cm), the varieties V73, V68, MDK, V8, V58, V5, SSD 35 are part of the same group. The V40 recorded the lowest average (110 cm). There is no significant difference between the 30 lines with regard to the NPR and PP parameters. For grain yield (RDT G), it differs significantly. The varieties V27 and TL1R have the highest yields with 1388.7 kg/ha and 1222.2 kg/ha respectively while V33 and V37 gave the lowest yields (333.3 kg/ha). In terms of stem yield (RDT T) (Table 2), the analysis revealed a significant difference between the varieties. The MDK and TL2R varieties have very high yields with 8111kg/ha and 7889kg/ha respectively while the L153-5 gave the lowest stem yield (2222kg/ha).

**Table 2: Performance of sorghum varieties at RIADI**

| VAR | 50% flo | HTR | MAT | NPR | PP | RDT G | POI100 GR | RDT T | IR | IB |
|---|---|---|---|---|---|---|---|---|---|---|
| V49 | 87,33bc | 156,7defghi | 102,33bc | 17,77 | 0,45 | 500abcd | 4bcd | 3111a | 1,93c | 0,35abc |
| L 28 | 85,67bcd | 160defghi | 100,67bcd | 16,33 | 0,40 | 444,4abc | 4,66b | 5000abc | 2,50abc | 0,32bc |
| V73 | 82,67bcdef | 170cdefgh | 97,67bcdef | 16 | 0,73 | 833,3abcd | 4bcd | 3778ab | 2,13bc | 0,36abc |
| V39 | 85bcd | 140dfghi | 100bcd | 20 | 0,66 | 777,8abcd | 4,33bc | 3667ab | 2,10bc | 0,35bc |
| V68 | 81,67bcdefg | 186,7cdef | 96,67bcdefg | 14,67 | 0,38 | 444,4ab | 4,33bc | 4000abc | 2,20abc | 0,35abc |
| V33 | 84,67bcd | 158,3defghi | 99,67bcd | 15,33 | 0,35 | 333,3a | 4,33bc | 5222abc | 2,56abc | 0,31bc |
| MDK | 98,33a | 240ab | 113,33a | 17,33 | 0,61 | 722,2abcd | 4bcdef | 8111c | 3,43a | 0,32bc |
| V17 | 80,33bcdefg | 121,7ghi | 95,33bcdefg | 21,67 | 0,85 | 1000abcd | 3,33cdef | 3222a | 1,96c | 0,39bc |
| V61 | 74,33defgh | 131,7fghi | 89,33defg | 18,33 | 0,8 | 833,3abcd | 4bcd | 5333abc | 2,60abc | 0,31bc |
| V8 | 77,67bcdefg | 188,3cde | 92,67bcdefg | 20,33 | 0,50 | 500abcd | 4,66b | 4667abc | 2,48abc | 0,27bc |
| V45 | 87,67b | 130fghi | 102,67b | 14,33 | 0,46 | 444,4ab | 4bcd | 2889a | 1,86c | 0,31bc |
| V19 | 80,33bcdefg | 125ghi | 95,33bcdefg | 19,67 | 0,50 | 555,6abcd | 4bcd | 3222a | 1,96c | 0,33bc |
| V40 | 75defg | 110i | 90,02defg | 12,67 | 0,50 | 500abcd | 3,33cdef | 4111abc | 2,23abc | 0,28bc |
| V47 | 82,67bcde | 213,3bc | 97,67bcde | 17,33 | 0,46 | 666,7abcd | 4,66b | 4444abc | 2,33abc | 0,42bc |
| V1 | 85,33bcd | 143,3defghi | 100,33bcd | 17,33 | 0,31 | 388,9a | 4bcd | 3222a | 1,96c | 0,35abc |
| V27 | 80,33bcdefg | 153, 3defgh | 95,33bcdefg | 18,33 | 0,68 | 1388,9bd | 4,33bc | 5556abc | 2,66abc | 0,60a |
| V13 | 74,33defgh | 113,3hi | 89,33defg | 20,67 | 0,78 | 444,4ab | 3dg | 4222abc | 2,26abc | 0,20c |
| V3 | 84,67bcd | 161,7defghi | 99,67bcd | 18 | 0,63 | 666,7abcd | 4bcd | 4556abc | 2,36abc | 0,32bc |
| V48 | 87,33bc | 180cdefg | 101,33bc | 17,77 | 0,56 | 555,6abcd | 433bc | 3889abc | 2,16abc | 0,29bc |
| V29 | 71,67efghij | 131,7fghi | 86,67efghij | 12 | 0,31 | 388,9a | 4bcd | 5000abc | 2,50abc | 0,36abc |
| V70 | 76,33bcdefg | 120hi | 91,33bcdefg | 16,67 | 0,50 | 444,4ab | 4bcd | 4778abc | 2,43abc | 0,28bc |
| V37 | 70,67eghijk | 128,3ghi | 85,67eghijk | 17 | 0,50 | 333,3a | 3,66bcdefg | 4556abc | 2,36abc | 0,20c |
| V16 | 74defgh | 126,7ghi | 80,2efg | 20,33 | 0,63 | 777,8abcd | 4bcd | 5222abc | 2,56abc | 0,35abc |
| V5 | 75,67cdefg | 165defghi | 90,67cdefg | 13 | 0,68 | 444,4ab | 3,33cdef | 4778abc | 2,43abc | 0,23c |
| V50 | 73,67defghi | 140dfghi | 88,67defghi | 17,67 | 0,56 | 722,2abcd | 4bcd | 4222abc | 2,26abc | 0,39abc |
| L153-5 | 64,33hjkl | 143,3defghi | 79,33hjkl | 18,33 | 0,55 | 500abcd | 4bcde | 2222a | 1,66c | 0,37bc |
| V58 | 75,33defg | 131,7efghi | 90,33defg | 16,67 | 0,66 | 833,3abd | 4bcd | 5667abc | 2,70abc | 0,35abc |
| TL2R | 71efghij | 260a | 86efghij | 16 | 0,58 | 1055,6abcd | 3dge | 7889bc | 3,36ab | 0,55ab |
| SSD35 | 62,67jl | 193,3cd | 77,67jl | 24,67 | 0,71 | 944,4abcd | 3,66bcdefg | 3333a | 2c | 0,39abc |
| TL1R | 98,33a | 265a | 113,33a | 24,33 | 0,95 | 1222,2abc | 6a | 5556abc | 2,96abc | 0,40bc |

Means followed by the same letter in the columns are not significantly different according to the LSD test at 5% probability.

## 3. GARIN MAIGARI

At the Garin Maigari level, there is no significant difference regarding the plant height parameters (HTR), stem yield (RDT T) and panicle weight (PP). The other parameters differ statistically depending on the varieties. For the 50% FLO and MAT parameters, the TL1G variety (El Bazanga) is the earliest with 84 DAS and the MDK is the latest with 107 DAS. For the numbers of panicles harvested (NPR), the SSD 35 variety gave the highest number with 26 panicles, the TLG2 and V70 varieties gave the same number of panicles (23 panicles) while the V5 (8.33 panicles) and V40 (9 panicles) gave the lowest numbers of panicles. The varieties MDK and TLG2 (MDW) gave the best grain yield (1111 kg/ha) while L153-5 was the least efficient with a yield of 222.2 kg/ha (Table 3). The average weight of 100 grains of the TLG2 and MDW varieties (66g) are the highest and those of L 153-5, V49, V1 (3.33g) the lowest.

**Table 3: Performance of sorghum varieties at Garin Maigari**

| VAR | 50% flo | HTR | MAT | NPR | PP | RDT G | POI100 GR | RDT T | IR | IB |
|---|---|---|---|---|---|---|---|---|---|---|
| V49 | 104,33ab | 140a | 119,3ab | 12ab | 0,23b | 277,8a | 3,33b | 6222a | 2,86a | 0,33ab |
| L 28 | 101,33ab | 113,3a | 116,3 | 11,67ab | 0,21b | 500a | 4b | 4111a | 2,23a | 1,91a |
| V73 | 100,67abcd | 128,3a | 115,7abcd | 8,67b | 0,16b | 277,8a | 4b | 10556a | 4,16a | 0,50b |
| V39 | 96,67abcd | 110a | 111,7abcd | 16,33ab | 0,35b | 444,4a | 4b | 7333a | 3,20 | 0,36b |
| V68 | 96abcd | 143,3a | 111abcd | 16,67ab | 0,35b | 388,9a | 4b | 10556a | 3,16a | 0,33ab |
| V33 | 99,33abcd | 121,7a | 114,3abcd | 17ab | 0,28b | 277,8a | 4,33ab | 6667a | 3a | 0,36b |
| MDK | 107a | 178,3a | 122a | 19,67ab | 1,20a | 1111,1b | 4,66ab | 5889a | 4,5a | 0,28b |
| V17 | 98abcd | 145a | 113abcd | 18,67ab | 0,56b | 500a | 4,33b | 11667a | 2,76a | 0,26b |
| V61 | 88,33bcd | 133,3a | 103,3bcd | 16ab | 0,30b | 444,4a | 4b | 6000a | 2,80a | 0,46b |
| V8 | 94abcd | 153,3a | 109abcd | 20,33ab | 0,46b | 555,6a | 4,66ab | 9444a | 3,83a | 0,36b |
| V45 | 101abc | 110a | 116abc | 16ab | 0,48b | 500a | 4,66ab | 6111a | 2,83a | 0,35ab |
| V19 | 88,33bcd | 170a | 103,3bcd | 17ab | 0,41b | 611,1a | 4b | 6111a | 2,83a | 0,45b |
| V40 | 98,67abcd | 131,7a | 113,7abcd | 9b | 0,18b | 333,3a | 3,66b | 3000a | 1,9a | 0,66b |
| V47 | 97,33abcd | 163,3a | 112,3abcd | 13ab | 0,23b | 333,3a | 4b | 10556a | 4,16a | 0,44b |
| V1 | 103,67abc | 108,3a | 118,7abc | 10b | 0,2b | 277,8a | 3,33b | 5444a | 2,63a | 0,57b |
| V27 | 94abcd | 118,3a | 109abcd | 14ab | 0,28b | 444,4a | 3,66b | 3333a | 2a | 0,47b |
| V13 | 93,33abc | 116,7a | 108,3abcd | 11,67ab | 0,18b | 277,8a | 3,66b | 5556a | 2,66a | 0,44b |
| V3 | 97,33abc | 136,7a | 123,3abcd | 16ab | 0,41b | 555,6a | 4b | 8889a | 3,66 | 0,38b |
| V48 | 98abcd | 160a | 113abcd | 15,33ab | 0,25b | 277,8a | 4b | 5889a | 2,76a | 0,52b |
| V29 | 87,67bcd | 128,3a | 102,7bcd | 12,67ab | 0,2b | 277,8a | 4b | 7667a | 3,30a | 0,44b |
| V70 | 90,67abcd | 125a | 105,7abcd | 23ab | 0,55b | 722,2a | 4b | 8111a | 3,34a | 0,38b |
| V37 | 89bcd | 11,7a | 104bcd | 21ab | 0,33b | 333,3a | 4b | 4444a | 2,33a | 0,33ab |
| V16 | 90bcd | 128,3a | 105bcd | 19ab | 0,41b | 555,6a | 4,33ab | 6333a | 2,90a | 0,41b |
| V5 | 94,67abcd | 165a | 109,7abcd | 8,33b | 0,23b | 277,8a | 4b | 4111a | 2,23a | 0,36ab |
| V50 | 87,67bcd | 116,7a | 102,7bcd | 18,33ab | 0,21b | 277,8a | 4,33ab | 4889a | 2,46a | 0,38b |
| L153-5 | 87cd | 116,7a | 102cd | 16,67 | 0,13b | 222,2a | 3,33b | 3778a | 2,13a | 0,50b |
| V58 | 89,67bcd | 121,7a | 104,7bcd | 13,33ab | 0,25b | 500a | 4b | 3111a | 1,93a | 0,59b |
| TL2G | 101,67abc | 183,3a | 116,7abc | 23ab | 1,10a | 1111,1b | 5,66a | 11111a | 4,3a | 0,30b |
| SSD35 | 92abcd | 155a | 107abcd | 26a | 0,31b | 500a | 4b | 7778a | 3,33a | 0,48b |
| TL1G | 84d | 156,7a | 99d | 17,67ab | 0,30b | 388,9a | 5ab | 7889a | 3,36a | 0,39b |

Means followed by the same letter in the columns are not significantly different according to the LSD test at 5% probability.

## 4. Combined analysis results from the 3 sites

The combined analysis of variance (Table 4) shows that there is a significant interaction between sites and varieties for six (6) parameters, namely: flowering 50% (50% Flo), plant height (HTR), physiological maturity (MAT), panicle weight (PP), grain yield (RDT GR) and 100 grain weight (POI 100 GR).

**Table 4: variances of the different parameters monitored**

| Sources of variance | 50% flo | HTR | MAT | NPR | PP | RDT GR | POI100 GR | RDT T | IR | IB |
|---|---|---|---|---|---|---|---|---|---|---|
| Variety (V) | 10,54* | 4,85* | 10,54* | 4,19* | 5,28* | 3,88* | 4,47* | 2,96* | 2,93* | 1,37ns |
| Sites (S) | 167,60* | 35,27* | 167,60* | 47,05* | 92,75* | 30,40* | 1,15ns | 17,12* | 17,13* | 6,62* |
| V x S | 3,46* | 1,83* | 3,46* | 1,27ns | 2,28* | 1,80* | 2,91* | 1,39ns | 1,39ns | 0,68ns |

**'ns' not significant, '*' significant**

## 5. Correlation between the studied parameters

At this level the correlation matrix between the parameters which allows us to see the link between the pairs of variables has been highlighted (Table 5). Indeed, a strong significant correlation is observed between the RDT G variable and the HTR with (r=0.29). The correlation between RDT G and RDT T is highly significant and positive with (r=0.15). The correlation between the RDT T and the NPR is very highly significant with a coefficient (r=0.21). The correlation between RDT G and MAT is highly significant and negative with (r=-0.15). The correlation between the RDT G and the NPR, as well as that observed between the RDT G and the PP, are also very highly significant with respective coefficients (r=0.48) and (r=0.75).

**Table 5: Correlation matrix between variables**

| | 50%Flo | HTR | IB | IR | MAT | NPR | POI 100G | PP | RDT G | RDT T |
|---|---|---|---|---|---|---|---|---|---|---|
| 50%Flo | 1 | | | | | | | | | |
| HTR | -0,131* | 1 | | | | | | | | |
| IB | 0,143* | -0.095ns | 1 | | | | | | | |
| IR | 0.227*** | 0.089ns | -0.076ns | 1 | | | | | | |
| MAT | 1.000*** | -0.131* | 0.1430* | 0.227*** | 1 | | | | | |
| NPR | -0.308*** | 0.218*** | -0.274*** | 0.216*** | -0.308*** | 1 | | | | |
| POI 100G | 0.193*** | 0.099ns | -0.099ns | 0.269*** | 0.193*** | 0.232*** | 1 | | | |
| PP | -0.234*** | 0.315*** | -0.245*** | 0.160** | -0.234*** | 0.617*** | 0.323*** | 1 | | |
| RDT G | -0.158** | 0.299*** | 0.243*** | 0.158** | -0.158** | 0.481*** | 0.286*** | 0.757*** | 1 | |
| RDT T | 0.227*** | 0.089ns | -0.076ns | 1.000*** | 0.227*** | 0.216*** | 0.269*** | 0.160** | 0.158** | 1 |

**'ns' not significant '***' significant at 0.1%; '**' significant at 1%; '*' significant at the 5% level.**

## 6. GGE Biplot Analysis

### 6.1. Environnent Vector Plot

The results showed a distribution of environments and genotypes following the two main components PC1 and PC2. The environments are represented by vectors in blue color and the genotypes by their names in green color. The angle formed by the environment vectors provides an estimate of their similarity. Analysis of the figure reveals that for grain yield, the vectors of the CERRA Maradi STATION and RIADI environments form an obtuse angle. These two environments are therefore totally different, on the other hand the CERRA Maradi and GARIN MAIGARI environments form an acute angle (less than 90°). They are similar and form a mega environment

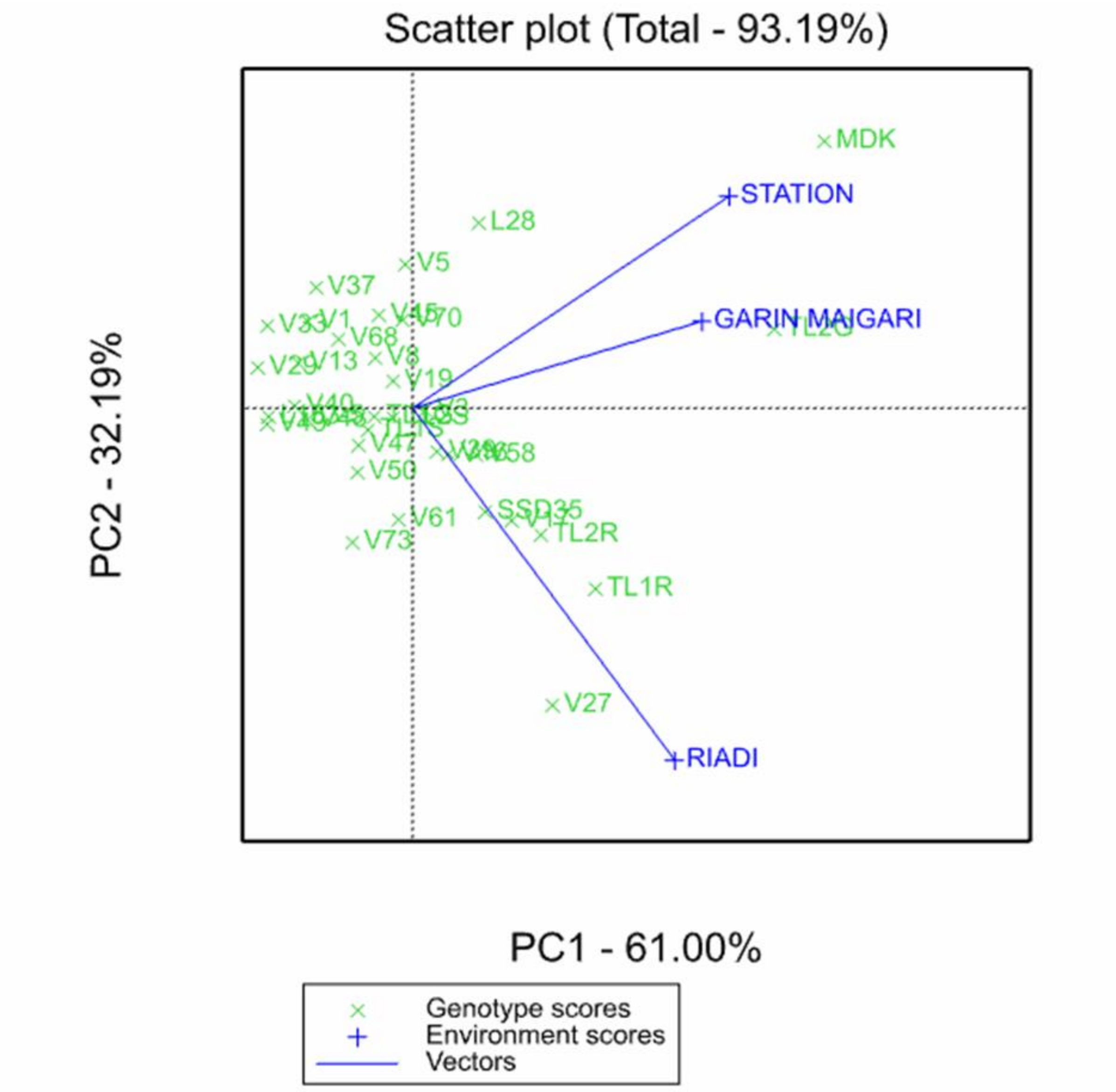


**Figure 2: Distribution of genotypes and environments for Grain Yield**

### 6.2. Expression of genotypes depending on environments

The projection of the genotypes onto the plane formed by the two principal components PC1 and PC2 gives a polygon whose vertices are constructed by the elite genotypes. The polygon is subdivided into several compartments by straight lines perpendicular to the polygon forming the mega-environments. Genotypes found in an area including an environment are best suited to that environment. These are the MDK and TL2G genotypes which are the most efficient in the mega environment constituted by STATION and GARIN MAIGARI, the V27, TL1R and V73 genotype in the RIADI environment.

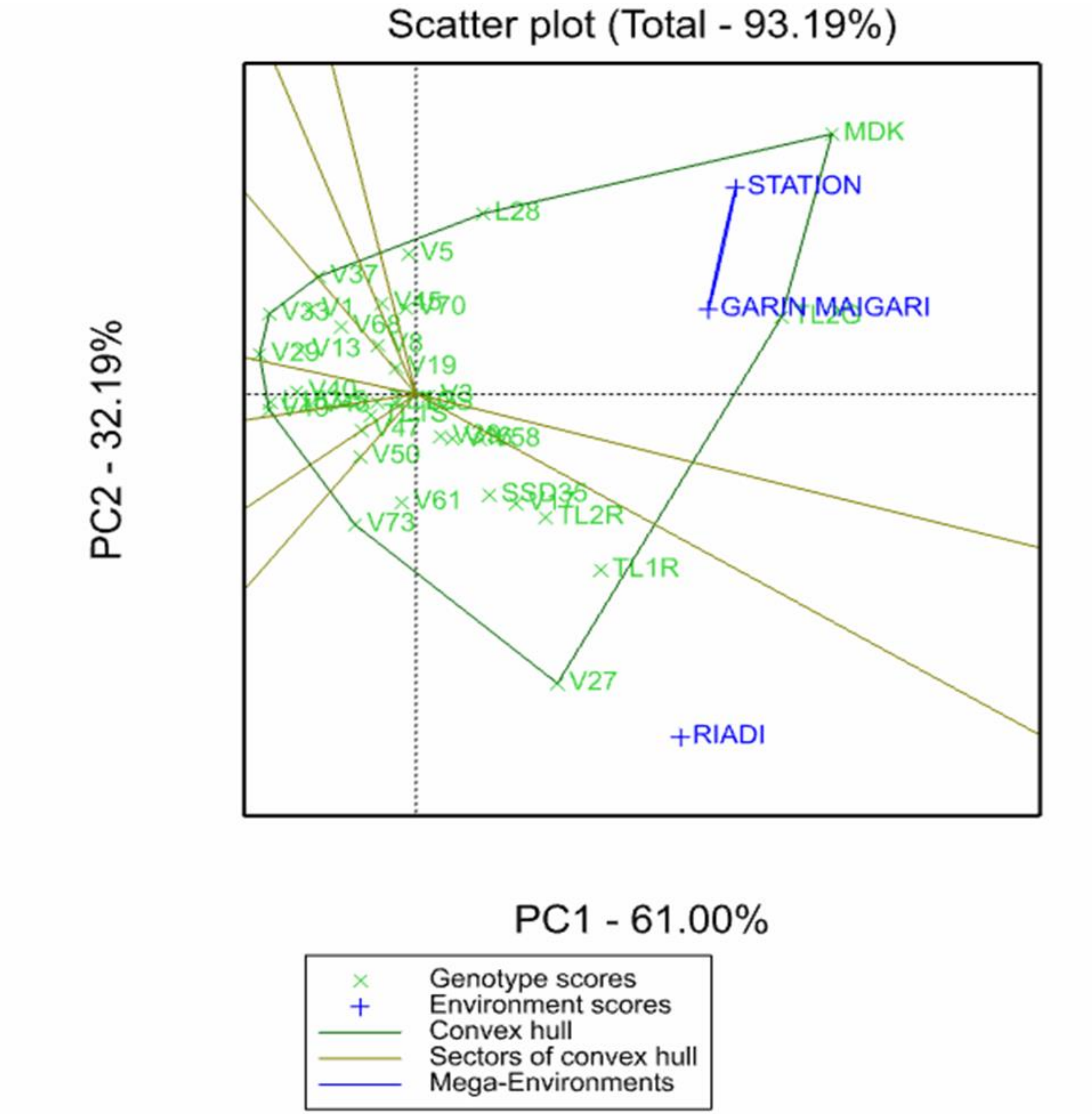


**Figure 3: Distribution of genotypes, environments and mega-environment for Grain Yield (RDT G)**

### 6.3. Comparison of genotypes

For the comparison of genotypes in terms of grain yield (RDT G) according to this analysis, the ideal genotype (which has the highest and stable average) is the one which is closer to the circle. Thus, the further we move away from the circle, the less efficient the genotype is. This is the TL2G genotype which has the highest average in terms of grain yield.

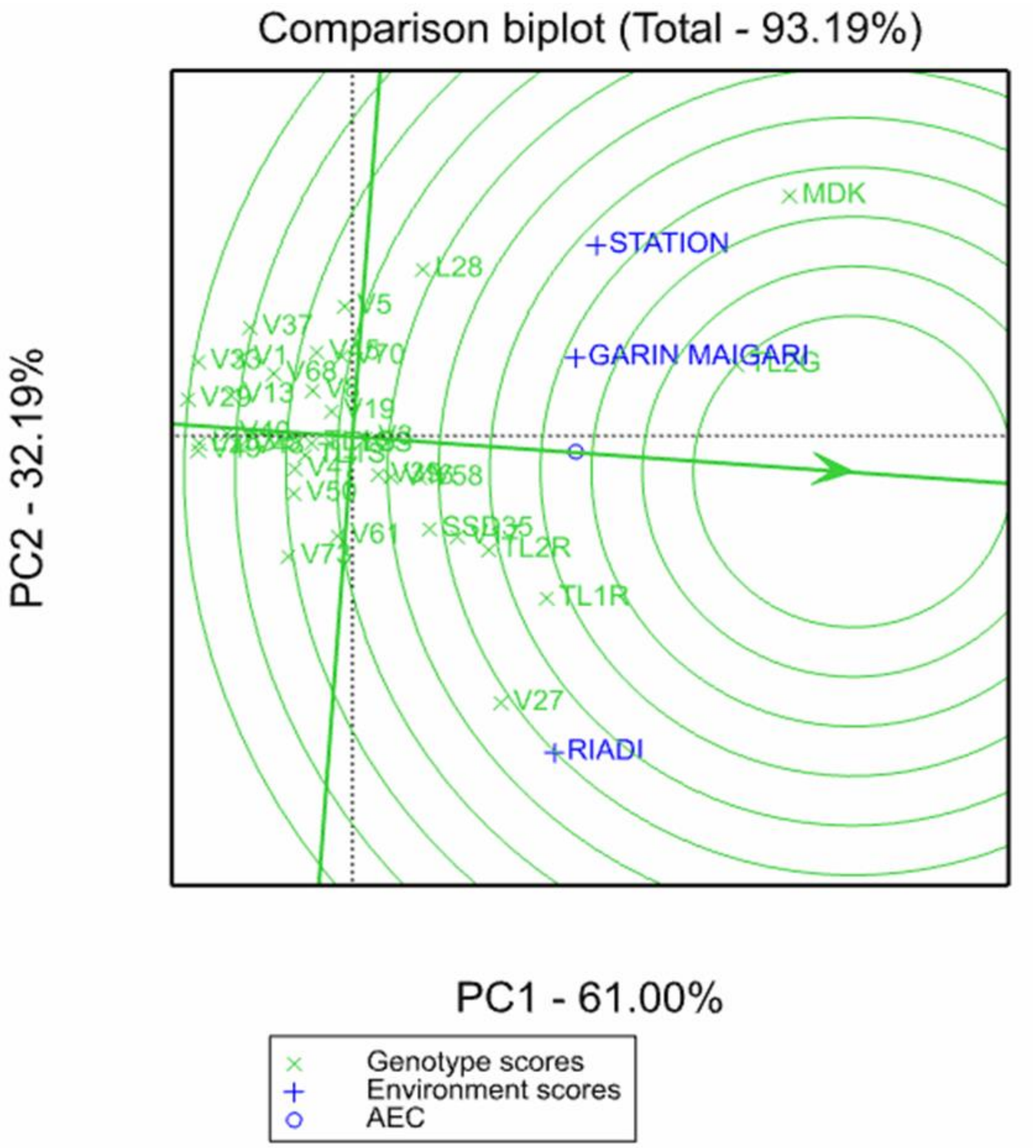


**Figure 4: Comparison of genotypes**

### 6.4. Comparison of environments

This analysis makes it possible to measure the representativeness of the environments and to define a benchmark environment and to use it as a reference for comparison, this “ideal” environment, or the average environment (indicated by a circle with an arrow in it representing the axis AEC). This environment is the most discriminating of the genotypes and the most representative compared to other environments. in the present study it is GARIN MAIGARI which is the most desirable for evaluating the performance of the genotypes.

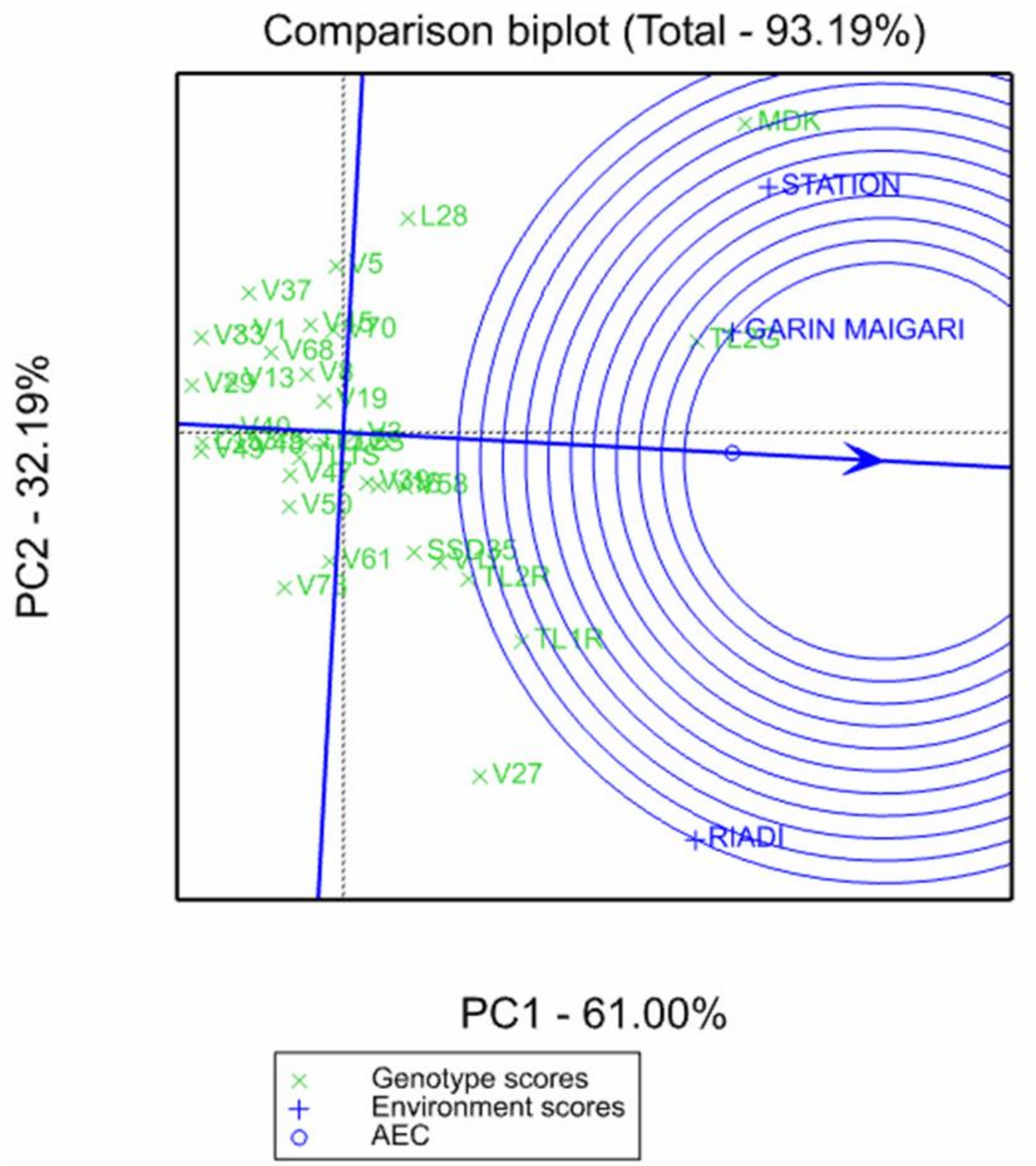


**Figure 5: classification of environments according to representativeness and discriminating capacity.**

### 6.5. Classification of genotypes according to environment

This analysis makes it possible to classify varieties according to their performance in an environment. The distance between axis and genotypes determines genotype performance in this environment. However, the smaller the distance between the axis and the genotype, the more efficient the genotype is in this site. For the RIADI site, the most efficient genotypes are among others V27, TL1R, TL2R, SSD 35, V61.

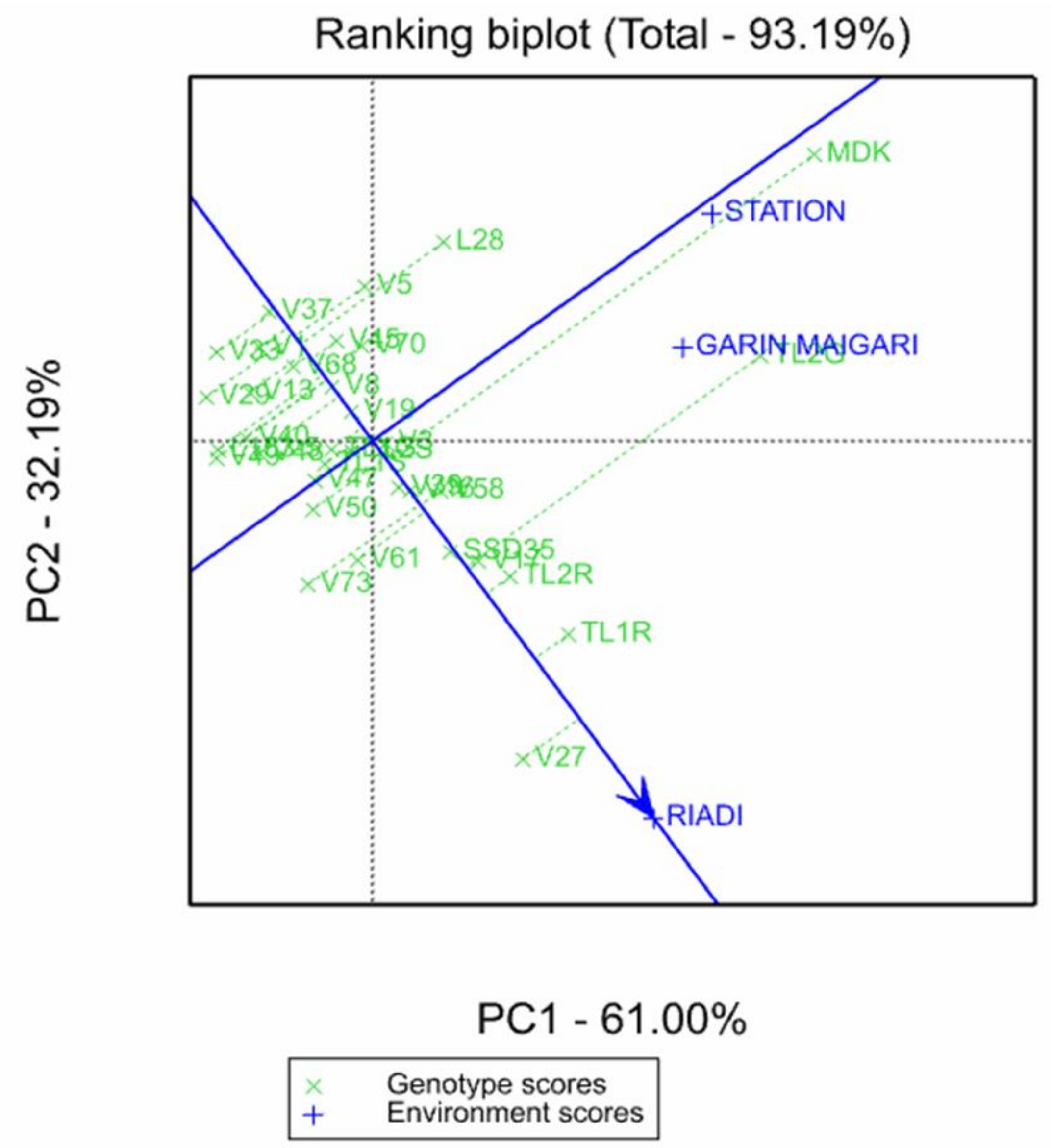


**Figure 6: Classification of genotypes according to environment**

## IV DISCUSSION

The results of the present study indicate a very large variability for the measured parameters. This variability is both genetic and environmental. The descriptive analysis confirms this variability, where we see that the variables differ between genotypes and between sites. Indeed, the analysis of variance for each site showed us a significant difference between the varieties for all parameters. The significance that exists between the majority of parameters for the different localities allows us to deduce that the different sites are varied.

On the other hand, the significant difference for all the characteristics studied with the exception of the number of panicles harvested, the stem yield, the harvest index and the threshing index for the interaction between environment and varieties reflects a particular influence for characters as mentioned by Gaufichon et al., 2010. He also indicated that the expression of genes can be modified depending on environmental conditions confirmed by the studies carried out by Garba et al., (2015) thus attesting that the varieties are generally developed based on traits that allow them to adapt to their environment. These traits are closely linked to the ecological conditions in the production areas. In other words, the variation observed for the traits measured is partly due to environmental factors coupled with genotypic differences.

Regarding correlation, it is very useful for selection work according to Siene et al. 2010. For our study, the analysis of the correlations between the measured parameters shows that many variables presented an interesting correlation from the morphological and agronomic point of view. However, we find between the grain yield variable (RDT G) and plant height (HTP), a highly significant and positive correlation. The latter explains that the higher the stems of the plant, the higher the grain yield. Likewise, a highly significant and positive correlation is observed between grain yield (RDT G) and stem yield (RDT T). This shows that the more stem biomass the plant produces, the more grain yield it has. The link can also explain the plant's ability to transfer assimilates to grain production. This positive correlation between the RDT G and the RDT T makes it possible to select genotypes which have a good ability to transfer assimilates for grain production. We also observe a positive correlation between the variable Height of plants (HTP) and 50% Flowering (50%FLO) which allows us to understand that precocity depends on the height of the plant in this study.

Late varieties have a higher height since the plant will take a long time to complete its cycle and therefore will have time for good vegetative development. This result is consistent with that of Illiassou, 2017 where he also found a significant and positive correlation between HTP and FL0.

There is a non-significant correlation between stem yield (RDT T) and plant height (HTP). This allows us to understand that for the present study, in sorghum, stem yield is not only linked to the height of the plants but a combination of several parameters such as stem diameter and number of leaves. This result contradicts that of Illiassou, 2017 where he found a significant and positive correlation between RDT T and HTP.

In other words, the results of the GGE Biplot analysis rank genotypes by their average yield performance and stability in a number of environments. An ideal genotype is one that is efficient and stable. In our study, the most efficient and stable genotypes are therefore V68, V3, V58. This result is in the same direction as that of Naroui et al. (2013) on wheat who found genotypes (14, 20, 21, and 22) more stable with appropriate yield.

This result shows that the effect of the environment plays a very important role in the expression of yield of certain varieties, which is why it is rare to find genotypes expressing their potential in several different environments. This is the case of a study on 10 sesame genotypes which highlighted a single GK01 genotype as the best cultivar for the 5 test environments (Boureima, 2017).

The genotypes SSD 35, V61, L28, V27, MDK have average high yields but they are not stable and the genotypes V 13, V 47, V 43, V19, V29, V8 are stable but very low yields (lower to the average).

These results corroborate those of Ménad et al. (2010) which stipulate that the stability of yields is independent of their values, and that genotypes with high yield are generally relatively unstable while it is generally the opposite for genotypes with medium or low yield. They also confirm the assertion of Yan and Hunt (2002) who indicate that overall stability is not necessarily a positive factor and that it is only desirable when it associates a high average return. (Ndiaye et al., n.d.).

## V. CONCLUSION

Sorghum is a critically important food crop worldwide. This crop is exposed to different factors that influence its production such as drought, diseases, pest attacks, lack or inaccessibility of improved varieties.

Varietal innovations have always been a key element of agricultural production. Evaluating the behavior of new varieties in the face of a diversity of environments is therefore an important issue for stakeholders, from those who select these new varieties to those who cultivate them or use the products.

Our study made it possible to evaluate agronomic performances depending on the sites. And the GGE BIPLOT analysis showed that grain yields were strongly influenced by genotypes, environments and genotype-environment interaction. Environments elicited different responses from genotypes and most of these genotypes showed environmental specificity.

This work carried out during the 2021 rainy season in the villages of RIADI, GARIN MAIGARI and at the CERRA-Maradi STATION noted very appreciable abilities of certain genotypes with regard to agro morphological variables and yields. The GGE Biplot analysis made it possible to identify mega environments. However, two mega-environments are determined for the grain yield variable. GARIN MAIGARI and STATION are similar and different from the RIADI environment. The genotypes most suitable for the mega-environment formed by RIADI and GARIN MAIGARI are MDK, TL2G, L28 and V5 while V27 and V73 are the best genotypes in the RIADI environment. This analysis also showed that GARIN MAIGARI constitutes the ideal environment (benchmark) and can therefore be used for genotypes with broad adaptation.

In addition, this analysis made it possible to identify certain genotypes such as SSD 35, V61, L28, V27, MDK which have high but unstable average yields and V 13, V 47, V 43, V19, V29, V8 which are stable. but producing very low yields (below average).

## REFERENCES

**Antoine W., 2009.** Contribution à l'étude des contraintes de stockage des céréales (mil, sorgho) en zone sud soudanienne du Burkina Faso, Mémoire pour l'obtention du Diplôme d'études approfondies (DEA), en science biologique appliquée. Université d'Ouagadougou, FAST, 46 p.

**Bassirou I., 2014.** Etude comparative de la phénologie et du rendement de deux variétés précoces de mil dans les conditions locales du foret classé de Dan Kada : HKP et SOSAT, mémoire de fin du cycle pour l'obtention du diplôme de licence, Université Dan Dicko Dankoulodo (UDDM) de Maradi, FASE, 27 p.

**Boureima S., Yaou A., Lawali S., 2017**. Seed yield stability and analysis of genotype x environment interaction of sesame genotypes in central south of Niger. Faculty of Agronomy and Environmental Sciences, University Dan Dicko Dankoulodo of Maradi. Journal of Animal and Plant Sciences, 2017. 34 (3): 5535-5547.

**GarbaN.M,Bakasso.Y,ZamanAllah.M,Atta.Mamane.M.IAdamou.M,Hamidou.F,Idi.S.S,Mahamame.A,Saadou.M. 201.Evaluation of agromorphological diversity of groundnut (ArachishypogaeaL.) in NigerAfrican Journal of Agricultural Research 10(5) :334-344Gauch H. G. J., Zobel R.W., 1996.** AMMI analysis of yield trials. p. 1–40. In M.S. Kang and H G Gauch (ed.) Genotype by-environment interaction. CRC Press, Boca Raton, FL

**Gaufichon. L, Prioul. J-L., Bachelier.B.2010**. Quelles sont les perspectives d'amélioration génétique de plantes cultivées tolérantes à la sécheresse. In''Fondation pour l'Agriculture et la Ruralité dans le Monde.91-93

**Hiama T., 2005.** Evaluation des caractéristiques morphologiques d'hybrides de sorgho guinea (*Sorghum bicolor* L. Moench), Mémoire d'ingénieur agronome, Université Polytechnique de Bobo-Dioulasso (UPB), IDR, 76 p.

**INS 2014a.** Le Niger en chiffres. Niamey, Niger, 128 p.

**INS 2014b.** Statistique de l'Agriculture, élevage et Pêche, Annuaire statistique du Niger 2009-2013, 245 p.

**INS., 2012.** Annuaire Statistique du Niger 2008-2012, 237 p.

**Louis S., 1995.** Réponse de la variété de sorgho CE 145-66 à l'alimentation en eau : effet du stress hydrique sur le rendement et la qualité des semences, mémoire de fin d'études pour l'obtention du diplôme d'ingénieur des travaux agricoles, école nationale des cadres ruraux de Bambey (E.N.C.R.), Sénégal, 66 p.

**Memento de l'agronome, 2002**. Ministère des affaires étrangères, CIRAD-GRET, édition 2002, 1691 p.

**Boureima S., Yaou A., Lawali S., 2017**. Seed yield stability and analysis of genotype x environment interaction of sesame genotypes in central south of Niger. Faculty of Agronomy and Environmental Sciences, University Dan Dicko Dankoulodo of Maradi. Journal of Animal and Plant Sciences, 2017. 34 (3): 5535-5547.

**Gauch HG and Zobel RW., 1996**. AMMI analysis of yield trials. In Genotype-by-environment Interaction (Kang, M.S. and H.G. Gauch, eds.), CRC Press, Boca Raton, FL: 85-122. 106.

**Gauch, H.G and Zobel R.W., 1997**. Identifying mega-environments and targeting genotypes. Crop Sci. 37:311-326.

**Gaufichon .L, Prioul. J-L., Bachelier.B.2010**. Quelles sont les perspectives d'améliorationgénétique de plantes cultivéestolérantes à la sécheresse. *In*''Fondation pour l'Agriculture et la Ruralité dans le Monde.91-93

**Kaya, Y., M. Akcura and S. Taner, 2006.** GGE-biplot analysis of multienvironment yield trials in bread wheat. Turk. J. Agric. For., 30: 325-33

**Naroui Rad M. R., Abdul Kadir M., Rafii M.Y., Jaafar Z. E. H., Naghavi M.R., Ahmadi F., 2013.** Genotype × environment interaction by AMMI and GGE biplot analysis in three consecutive generations of wheat (Triticum aestivum) under normal and drought stress conditions, AJCS 7(7): 956-961.

**Ndiaye, M., Adam, M., Guisse, A., & Cisse, N. (2019**). Performances agronomiques et stabilité phénotypique de génotypes de Sorgho ( Sorghum bicolor ( L .) Moench ) au Sénégal :une étude des interactions, (August 2018). https://doi.org/10.4314/jab.v125i1.10

**Sadi S., 2011.** Evaluation agro morphologique et étude de la synchronisation florale des parents mâles et femelles de 66 hybrides du sorgho, mémoire en vue de l'obtention du grade de master2, Université de Ougadougou, Unité de formation et de recherche en science de la vie et de la terre, 93 p

**Yan W., Holland J. B., 2010**. A heritability-adjusted GGE biplot for test environment evaluation. Euphytica, 171: 355–369

**Yan, W. and N.A. Tinker., 2006.** Biplot analysis of multi-environment trial data: Principles and applications. Can. J. Plant Sci., 86: 623-645

**Yan, W., L.A. Hunt, Q. Sheng and Z. Szlavnics., 2000**. Cultivar evaluation and mega-environment investigation based on the GGE biplot. Crop Sci., 40: 597-605

**Yan, W., P.L. Cornelius, J. Crossa and L.A. Hunt., 2001**. Two types of GGE Biplots for analyzing multi-environment trial data. Crop Sci., 41: 656-663.